RESEARCH ARTICLE

Application of Tower Girder Asynchronous Construction Technology

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Abstract:When constructing the tower beam in a traditional way, the tower beam will be simultaneously constructed with the tower column, it asks for a complicated construction procedure, difficult construction organization, long operating cycle, and highly increased construction cost. With the progress of technology, Asynchronous construction scheme of the tower column and tower beam is adopted and applied. This paper is based on the case of asynchronous construction of the H-type cable tower and beam of the six large-span Ao jiang Bridges .

Keywords: cable stayed bridge; cable tower; beam; Asynchronous construction

1. Project profile

The main bridge of Aojiang bridge is 52+88+320+88+ 2m double tower cable-stayed bridge. The cable tower of the main bridge adopts h-type structure, with a total height of 102.4 meters, the Tower column of which is an octahedral single cell box girder. The beams construction includes both the upper and lower beams for construction, all are prestressed concrete box girder with variable section. The bottom surface is a circular arc, with a radius of 75.391 meters. The cross span is 34.5 meters. The bottom Beam is + 28.775 meters, and the height changes from 5.5m to 7.5m. The roof and floor are 5.6 m wide. The thickness of the web is 1.0 m. The thickness of the top and bottom plate is 0.8 m. Two vertical partitions with thickness of 3.8m are arranged under vertical support. The lower crossbeam is decorated with 44 bands of 17φS15.2 teel strands.

The top elevation of the upper beam is +95.4m, the height is gradually changed from 5.0m to 7.0m, the top width is 6.0m, the bottom width is 6.0m, the thickness of the web is 1.0 m, and the thickness of the top and bottom plate is 0.8m. Two vertical partitions with thickness of 2.2m are arranged at the tower arm. The upper beam is decorated with 34 bands of 17 ivy S15.2 steel twisted wire.

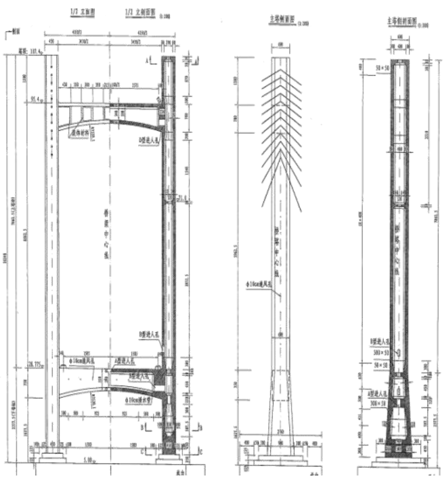

Figure 1.1. The structure diagram of cable tower

Figure 1.2. Bridge rendering

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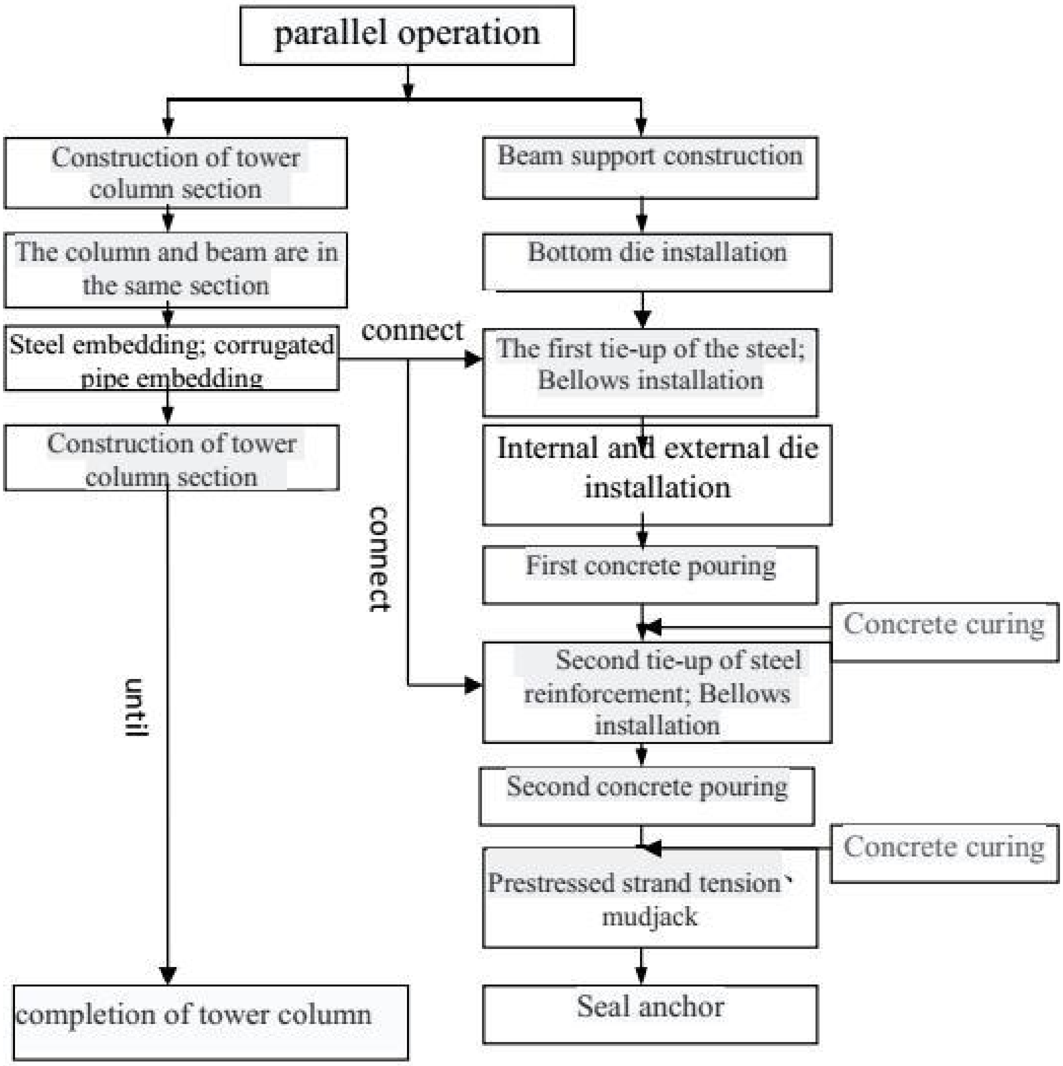
H-type tower column and beam are constructed asynchronously, which means that both tower column and beam are constructed in parallel, and the construction time of beam lags behind that of the tower column. The pillar and beam are in the same section. During the construction of tower column, the beam is connected with the embedded steel sleeve and corrugated pipe, and the chipping treatment is carried out after the completion of casting. In the construction of beams, steel pipe supports, formwork installation, steel bar binding, corrugated pipe installation, concrete pouring, prestressed tensioning, grouting and anchor sealing are carried out through tower crane or truck crane.



3. Construction quality control

3.1 cable-tower construction

When the tower column is built to the same section of the beam, in order to ensure the connection between the steel bar and the beam, the tower body shall be embedded with a straight thread connecting the sleeve, and the position shall be accurately embedded. The corrugated pipe should be installed in an accurate position, and the end socket adopts a large type of corrugated pipe, which is easy to connect with the beam, the concrete lap needs chipping. The specific quality control steps are as follows:

(1) To guarantee the accuracy of the embedded location of the rebar, the embedded steel positioning mesh can be processed according to the drawing spacing. In addition, after the plate installation is completed, the inner side shall be welded to ensure no displacement occurs during the concrete pouring process;

(2) In order to prevent grouting in the inside of straight threaded sleeve connected with steel bar during concrete

pouring, make sure the end of the sleeve should hold against the template, and the inner side of the sleeve can be filled with sponge strips and wrapped with tape.

(3) In order to ensure the position of the corrugated pipe be accurate, the control coordinates shall be based on the top elevation of the previous section and the concrete end face. To prevent end corrugated pipe from grouting, Geotextile plugging and tape wrapping should be used. In addition, to prevent the corrugated pipe from deforming during the concrete pouring process, the inner liner shall be installed.

(4) Chipping treatment of cross - beam lap surface shall be carried out in advance. During the process, the existing clamping platform can be used to avoid the erection of temporary support for subsequent beam construction. To ensure the position of the chiseling surface be accurate, the four-point position of the control end should be measured, using the ink line to flick the line, and then using the grinding machine to chisel the side line, after that the edge line is cut with a grinding machine, and the electric hammer is used to cut the wool in to the surface.

Figure 3.1.1. Construction surface chipping effect diagram Figure 3.1.2. Positioning mesh of preembedded steel bar of cable tower

3.2 Construction of beam support

Considering that the span of h-type cable tower reached 34.5 meters, the floor steel pipe support scheme is adopted for the erection of beam support after the discussion of many experts.

Specific construction quality control points are as follows:

（1）Considering that the height of the single steel pipe pile of the upper beam reaches 55.7 meters, the flange plate is adopted for the steel pipe pile docking in order to accelerate the construction progress and improve the efficiency. After processing the flange plate in the rear field, the vertical degree shall be strictly controlled and controlled within 2mm to ensure that there is no horizontal joint. After processing, the flange plate shall be transported to the construction site by tower crane and connected with high-strength bolts.

(2) The welding of all flat scissor brace and floor steel tube and embedded steel plate shall be fully welded without leakage welding and desorption. All flat joint, scissor brace and floor steel pipe should be fully welded with embedded steel plate, no leakage welding and no off welding should occur, the important parts need to be welded and added stiffened plate to enhance the local bearing capacity.

Figure 3.2.1. Pipe pile butt flange Figure 3.2.2. Setting of support sandbox

(3) Vertical degree control is required for steel tubular piles, and the total-station instruments are used for measurement and controlled within 1%.

(4) In order to control the top elevation, the sand box method can be adopted to control the elevation accuracy within 3mm, or to lower the sand box, so as to lower the load bearing beam on top of the bracket and facilitate the removal of the bottom model of the beam.

3.3 Template Assembly

The bottom surface of the beam is circular arc. In order to ensure the bottom arc structure, the truss steel mould, block processing and bolt connection should be adopted. The side mould is also the steel mould. Considering that the beam will be cast twice, mold turning construction can be used to save cost. The inner mould is made of bamboo plywood and square wood, which will be processed, and installed on site. The key points of quality control are as follows:

(1) Mould plate processing is carried out by a professional manufacturer with high precision. Before the delivery, project personnel and supervisors shall jointly supervise the trial production in the manufacturer's, and all quality indicators shall meet the requirements before delivery.

(2) The mould plate shall be polished, and all iron scrap of the template shall be cleaned by using a grinding machine, and professional mould remover shall be evenly coated under the weather conditions of sunshine.

(3) For the accuracy of the template. Since the bottom die is assembled in blocks, each template shall be accurately adjusted during the measuring process. When installing the side mold, the pull rod bolt and the hand pull gourd are used to carry out accurate measurement and adjustment, and precision error should be within 3mm. When installing the internal model, the dimension of the structure is controlled by the positioning bar, the perpendicularity is controlled by a horizontal ruler. The height of the roof inner mold is controlled by the inner support bracket, and the accuracy is within 3mm. All fine adjustment of the template shall be monitored by the measuring professionals throughout the whole process.

(4) When assembling the template, side bottomed method is adopted. The bottom of the side die shall be pressed against the outer surface of the bottom die. During the second formwork installation, the inner and outer molds should be close to the top surface of the concrete poured in the first time without any space. To ensure that there is no leakage of grouting at the bottom of the template and at the joints, double-sided glue or putty can be pasted at the joints to seal the joint between the bottom of the template and the poured concrete. At the same time, in order to ensure the top surface of the side die is in the same horizontal plane, the bottom surface should be in the same control level, and the limit plate can be welded on the side of the bottom die.

Figure 3.3.1. Template grinding

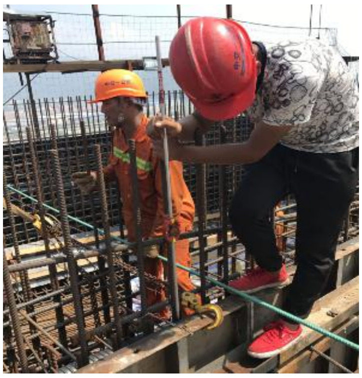


Figure 3.3.2. fine adjustment of measurement

3.4 Binding of reinforcement

Steel bar binding is an inevitable process of every structural body. The spacing between steel bar binding and the size of frame are important quality control points. The construction requirements of the beam are as follows:

(1) Semi-finished steel processing quality need to strengthened, especially the processing of steel Angle, Each batch of semi-finished products require spot inspection by on-site technicians and quality inspectors, and the unqualified semi-finished steel bars will be resolutely abandoned

(2) The crossbeam is connected with the steel sleeve of the tower column, and the quality of the connecting sleeve must meet the design and specification requirements as the basis, ensuring that each part of the sleeve rotates into the steel joint accounts for 1/2, and the steel sleeve wire shall not be exposed more than 2p.

(3)The reinforcement spacing control can be constructed by drawing point method and pull line method. The drawing point method is to mark the position of the reinforcement on the template or on the hook bar according to the space of reinforcement in the drawing, so as to bind the reinforcement bar. The pull line method controls the total position of reinforcement line by controlling two points.

Figure 3.4.1 The connection of Beam reinforcement and embedded sleeve Figure 3.4.2 the pull line method controlling the reinforcing bar plane

3.5 Bellows installation

(1) The connection between the embedded corrugated pipe of tower column and the corrugated pipe of beam is the key control procedure. First of all, when tower column is being poured, the joint pipe at the junction of the beam adopts a large type of corrugated pipe. Secondly, the beam corrugated pipe is inserted into the embedded corrugated pipe joint of the tower column, and the outside joint is sealed with glass glue, and wrapped with tape.

(2) For the Bellows linear control, the position of embedded bellows should be accurate and controlled by measuring control points. The corrugated pipe line in the beam can be controlled by the pull line at both ends of the tower column. Corrugated pipe should be positioned with spacer bar according to design requirements. For the circular arc corrugated pipe, a vent should be set at the highest point to ensure the full grouting.

(3) The steel strand should be bunched in advance. In high-altitude operation, late binding is not easy to operation, and the space on both ends is narrow, and it is very difficult to thread the beam at the later stage. Therefore, it is necessary to bunch the bundle in advance. It should also be noted that the measurement of the material length of the steel strand should meet the requirements of both ends tension.

3.6 Concrete pouring

Due to the large volume of beam concrete, it will be poured twice. The construction requirements are as follows:

(1) Clean the bottom surface before pouring, using high-pressure water gun for washing and manual cleaning, removing the debris to prevent the bottom surface from containing debris after pouring.

(2)There are two times of casting, the connection surface shall be treated with chipping. After the first pouring, the bottom abdomen surface shall be fully chipped, and the concrete slag shall be cleaned by air compressor or high-pressure water cannon.

(3) The casting is carried out by ground pump or automobile pump. It should be symmetrical pouring on both sides of the beam during casting to ensure stress equality and to avoid cold joints. The interval time of concrete pouring for a single part should not be too long and should be kept within 30min. Vibrate evenly to ensure no leakage over vibration and avoid touching corrugated pipe during pouring. During the process of pouring, a person should be arranged to carry out bracket observation.

(4) Concrete curing is carried out after the initial setting of casting. It is necessary to arrange a person to cover the

geotextile immediately and sprinkling water for seven days without interruption. For the concrete pouring top surface elevation control, the height should be 3~5cm higher than the design level after the first pouring to ensure that the second turnover can cover concrete roof of the first pouring, so as to ensure no leakage of slurry and the flatness of butt face. The top elevation of the secondary casting is at the time of template installation. The measurement precision adjustment is of top elevation, error can be constrained below 5mm. In addition, two urface finishing will be carried out by combining manual cleaning surface and channel steel drawing surface with high flatness, so as to ensure that the top surface flatness is controlled within 5mm.

4. Safety protection

Beam construction, the work high above the cable tower and beam cross operation, all of them have a great potential safety hazard that we must fully consider the whole construction process of hazards, and take reasonable measures to eliminate the hazards.

4.1 The bracket is equipped with safety protection

For the upper beam bracket adopts steel pipe pile flange butt joint and horizontal joint, scissor brace welding, Safety channels shall be set up on both sides of each pipe pile butt joint, setting up the secure channel up and down, and hanging for network in each layer of pipe pile butt.

4.2 cross operation protection of tower and beam

Cable tower and beam parallel operation, inevitably the beams are being constructed at the same time as the towers on the top are being constructed. To prevent falling objects, a falling objects platform should be installed on the upper part of the beam.

4.3 safety protection of beam operation

For the high-altitude operation of the beam, it is particularly important to protect the safe passage on both sides of the beam. It can be processed by working steel mould block, welded with distribution beam on site, laid by plank or steel plate.

Figure 4.2.1. Fall-resistant platform of Cross-working

Figure 4.3.1. Safety protection on both sides of the beam

5. Analysis of work efficiency

The cross beam and cable tower are constructed asynchronously, and the construction of two separate projects is carried out in parallel. Without any influence, the construction progress was greatly accelerated. In order to avoid the stagnation of tower construction due to synchronous construction, only the above beams are being constructed. According to the most ideal construction organization arrangement, a comparison table of synchronous and asynchronous construction cycles is made. See the table below

Construction Process	Workday	Start Time	Finish time	Note
Tower column construction to the same section of the beam (19 sections)	9	2017/8/7	2017/8/15	
Tower column construction to the same section of the beam (20 sections)	9	2017/8/16	2017/8/24	
Pillar Continue construction until completion (24 sections)	36	2017/8/25	2017/9/29	The construction efficiency of single section is calculated according to 9 days
Beam support construction	35	2017/7/20	2017/8/24	The construction height of the beam should be lower than the clamping platform
2 times pouring of the beam	40	2017/8/24	2017/10/3	Synchronous operation with the tower

Table 5.1. Asynchronous construction schedule of upper beam

Construction Process	Workday	Start Time	Finish time	Note
Tower column construction to last section of the beam(18 section)	9	2017/7/28	2017/8/6	
The hydraulic clamping die body on the side column of the beam is removed	3	2017/8/7	2017/8/9	
Beam support construction	42	2017/7/5	2017/8/16	After the inner clamping frame is removed, transverse load-bearing beam and ox leg can be installed
Pouring construction of first time of beam and tower section 19	25	2017/8/17	2017/9/10	Synchronous construction results in increased workload and working days
Pouring construction of second time of beam and tower section 20	25	2017/9/11	2017/10/5	Synchronous construction results in increased workload and working days
Construction of section 21 of tower pillar	10	2017/10/6	2017/10/15	The lateral mould of the beam shall be installed with the operating platform
Construction of section 22 of tower pillar	12	2017/10/16	2017/10/27	It takes 3 days to install the clamping die body on the side of the beam
Construction of section 23 of tower pillar	9	2017/10/28	2017/11/5	
Construction of section 24 of tower pillar	9	2017/11/6	2017/11/14	

Table 5.2. Synchronous construction schedule for upper beam

According to the comparison between the two tables above, it can be concluded that under the optimal work plan, only the asynchronous construction period of upper beam and cable tower is 41 days ahead of the synchronous construction. But because of considering the synchronous construction requirements process cohesion is very close that easy to cause the process connection does not reach the designated position, and the actual construction period will be extended. Therefore, asynchronous construction greatly speeds up the construction progress, improve construction efficiency.

6. Cost analysis

Cost type	Contrast type	Reduce shift/day/ton	Day/table price (yuan)）	Cost reduction (ten thousand yuan)	note
Mechanical fee	Tower crane	41	1800	14.76	2,41 days
	Construction of lift	41	600	4.92	2,41 days
Artificial cost	Ordinary workers	738	250	18.45	18,41days
The template fee	Finalize the design die of the tower beam Overlap chamfering	9.5	6000	5.7	
sum				43.83	

Table 6.1. Cost comparison of Asynchronous construction and synchronous construction of tower beams

Based on the analysis of synchronous construction, the asynchronous construction cycle and mechanical cycle are shortened, and the service time of two tower cranes and two construction lifts are reduced by 45 days.The construction contact surface between the cable tower and the beam is not required to re-customize 4 sets of chamfering formwork, and the weight of the formwork is reduced by 9.5t. A total of 18 construction workers are employed in the beam and tower columns. The asynchronous construction reduces the removal and reinstallation of the clamping mould frame of the tower, and can be used for cross construction, with less labor input.

From the above table, it can be seen that the direct cost of the asynchronous construction of the tower beam is 43,8300 yuan. There are two beams on the top and bottom of the tower column and two towers on the whole bridge, so the direct economic benefit can save the total cost: 4 times 43.83= 1.7532 million yuan.

7. Conclusion

Through the AoJiang six bridge cable tower and beam synchronous construction examples of applied research, can draw tower beam asynchronous construction, not only control the construction quality and safety protection work effectively, has obtained the good effect of construction, but also greatly improve the construction efficiency, speed up the construction progress and save construction cost greatly. The construction experience of this project is expected to provide certain reference value for similar projects.

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